50X1-HUM

Page Denied

Next 2 Page(s) In Document Denied

Declassified in Part - Sanitized Copy Approved for Release 2011/11/02 : CIA-RDP80T00246A017500030001-4

Proton Bombardment in Aurora

Yu.I.Galperin
Institute of Physics of the Atmosphere
U.S.S.R. Academy of Sciences
Moscow

Summary

The paper describes developments in observations of recently discovered new type of aurora the proton aurora i.e. "hydrogen field" which systematically appears in the auroral zone often at quiet magnetic conditions and moves to equator with rising magnetic disturbance. The hydrogen field is a nearly homogeneous wide band with borders along magnetic parallels. There is no other certain evidence on concentration of hydrogen emission in any other distinct auroral form. The magnetic zenith emission profile is nearly constant possibly with only minor variations. Published data cannot serve to derive with certainty the height of hydrogen emission in hydrogen field and initial proton energy spectrum at low energies.

The discovery of proton aurora as distinct phenomenon completes the picture of particle bombardment in disturbed upper atmosphere and stresses the lack of understanding of auroral accelerating mechanisms.

Observational results

1.1. Introduction

First auroral spectra with broadened hydrogen emission were obtained by Vegard in 1939 (1). Later observations of H_β (2,3) and H_α, H_β and H_γ(4,5) confirmed identification of registered emissions as hydrogen lines and proved that boradening is caused by doppler effect. Meinel (6,7) obtained doppler profiles separately from magnetic zenith and magnetic horizon and showed that emitting hydrogen atoms are moving approximately along magnetic lines of force and it was confirmed directly by Gartlein[8] by simultaneous spectrographing of fixed point of the same homogeneous arc in magnetic zenith and magnetic horizon from two stations.

1.2. Morphology of proton bombardment

Sistematic hydrogen emission studies at the auroral and subauroral zone (9 - 12) showed that usually before local midnight the region of proton bombardment shifts gradually from north to the south (in the Northern hemisphere) and after local midnight back from south to north, though sometimes much more complicated picture of repeated movements can be seen. Region of proton bombardment, "the hydrogen field" may be described as wide band of nearly homogeneous brightness. The borders of this band lay approximately along magnetic parallels (11) from horizon to horizon. Latitudinal spread is at least up to 15° while the lowest observed value is about 1° (11). To the north from hydrogen field (in the Northern hemisphere) the usual aurora [illegible] excitated by electrons in situated. Regions of proton and electron bombardment are usually separated by dark emissionless band (11,12,13). For higher magnetic activity both these regions move to south (10, 12, 13, 14). But in auroral zone hydrogen emission may appear during quiet magnetic field (9, 10, 15). These conclusions are in good agreement with earlier statistical results by Gartlein (16) and Montalbetti and Jones (15). With such picture the majority of earlier observations of auroral hydrogen such as by Vegard (2, 3), Fan and Schulte (17), Omholt (18, 19), Romick and Elvey (20) and others can be put into agreement.

Sometimes however hydrogen emission is registered simultaneously with usual electron aurora. The regular picture described above is disturbed especially during strong magnetic storms.

Hydrogen bombardment at zenith on low latitude stations is registered much rarely than electron bombardment. Apparently hydrogen field is surrounded from the south as from the north by regions of electron penetration (14). Many measurements have been made with the aim to find the enhancement of hydrogen emission in any usual bright sharp defind auroral form, but all with negative result (11).

In the auroral zone the hydrogen emission may be observed nearly every night with the intensity of the H_α line at least 100 R (9,11).

<u>1.3. Height luminosity distribution</u>

Measurements of brightness distribution of hydrogen emission in the function of zenith distance were made by different methods (7, 9, 11, 19). But if the geographical extent of hydrogen field at the moment of observations is unknown, the brightness distribution measured from one station can not allow to construct the height luminosity distribution. For this must be used precise simultaneous observations from a number of stations or rocket measurements in L_α line similar to airglow height determinations are needed.

According to Rees (21) detailed photometrical triangulation of typical hydrogen field gave for height of lower edge 106 km and sharp intensity decrease with height above maximum. But observational method and details are not mentioned.

1.4 Hydrogen line profiles

Extensive observational material have shown that in overwhelming majority of cases auroral hydrogen profiles are practically identical within observational errors.(3, 5, 6, 8, 9, 18, 19, 22, 23, 24, 25) Only some cases of "narrow" profiles in magnetic zenith have been stated (8, 22, 23). Small variations in H_α and H_β zenith profiles such as different displacement of intensity maximum, the rate of the intensity decrease in the violet tail at least partly are due to contamination of hydrogen radiation scattered from high magnetic zenith angles and often (especially with low resolution) hardly can be discriminated from blending bands. Meanwhile some variations may be significant. More detailed fast observations with high resolution are needed.

In any case, not a single magnetic zenith profile is published or stated with the intensity maximum in the energy range $\geq$10 кэв

1.5 Balmer decrement

Some information may be gathered from Balmer decrement of auroral hydrogen (relative intensities of Balmer lines) but the measurements are very difficult and there are still only few data. These are described in the following table.

Author	$I(H_\alpha)$	$I(H_\beta)$	$I(H_\gamma)$
Vegard (8)	7	1	-
Galperin (9)	-	1	0.38
Shuyskaya (26)	2.8 [illegible]	1	0.9 [illegible]
Doehr (27)	$1.65^{+0.58}_{-0.34}$	1	-

Successive intensities given by Doehr (27) apparently lead to conclusion that $I(H_\alpha)/I(H_\beta) \sim 2$ in periods of low intensity of (0,2) $1NGN_2^+$ band, but that $I(H_\alpha)/I(H_\beta) \sim 1$ during auroral break-ups. All these measurements apparently were not corrected for contamination of hydrogen radiation scattered from directions out of line of sight. So any conclusions about possible variations of Balmer decrement must be postponed.

Higher Balmer numbers than H_γ and Paschen lines have not been detected for the present with certainty.

1.6 Intensity correlations

Many authors finded correlation between hydrogen lines' intensity and high-altitude forbidden atomic emissions 6300-6364 [OI] and 5200 [NI] (5, 9, 13, 18, 20, 27, 28), but Evlashin (10) obtained contrary result. Ivanchuck (28) showed that mean intensity ratio of $I(H_\beta)/I[(0-2)1NG]$ rises together with ratio $I(5200)/I[(0-3)1NG]$. It was found (9) that in the spectra with hydrogen emission not only forbidden but often permitted atomic lines are also relatively enhanced which makes such spectra similar to ones of high altitude type A red aurora, and this was confirmed in (28).

Vaisberg (29) by extensive studies with auroral spectrometer showed that in hydrogen field the intensities of all strong emissions from ultra-violet to infrared regions are nearly proportional to H_β intensity. But in comparing these with spectra of electron aurora some peculiarities may be found for example, in hydrogen fields the relative intensity of Meinel bands of N_2^+ is lower and the intensity of 5004 NII is higher. The ratio $I(H_\beta)/I[(0,2)\,1NG] \sim 1$ in hydrogen fields and may be up to 1,5.

Some cases are reported when the ratio $I(H_\beta)/I[(0,2)\,1NG] \gg 1$ (20, 23, 30) and simultaneously H_β zenith profile become "narrow" (23).

1.6. Direct measurements of auroral protons

In the IGY early in the 1958 two series of rocket auroral measurements were performed. In one series (30) in four cases energetic ionic (most probably proton) beams were detected. Their integral energy spectra for energies more than about 160 kev. can be described by power law with $\gamma \sim -1,2$. For energies less than about 160 kev. the spectrum is more flat. The ionic flux is isotropic in the pitch-angle range from 0^0 to 75°. The most intense flux (with steep energy spectrum) was detected in situation similar in description to hydrogen field. In the other series (31) in the case also according to description similar to hydrogen field the flux of the form $J(>E) \approx 2{,}5 \left(\frac{E_{kev}}{1000}\right)^{-1,5} cm^{-2}\, sec^{-1}\, ster^{-1}$ was detected. Simultaneous ground observations of H_β with auroral spectrometer showed $Q(H_\beta) = 6 \cdot 10^7$ photon/sm^{2}sec. and intensity of integral auroral light registered by photomultiplier with S-11 spectral sensitivity curve as 0,05 erg /cm^{2}sec.

2. Theory of auroral hydrogen emission

2.1. Emission rate per incident proton

When a proton beam passes through a gaz (or gas mixture) a number of charge-changing elementary processes take place which lead to creation of neutral atoms and negative ions. Fractions of the total moving beam with charges "+" , "o" and "-" can be found from equations given in (3[illegible]). Some processes lead to appearance of the excited atoms. The H^- fraction of incident proton in the molecular azot, oxygen and hydrogen beam do not exceed 2% and usually its role is not taken into consideration though respective cross--sections are not known.

The most important characteristic of proton beam emissivity is the dependence Fnn' (v) of photon emission rate per incident proton per unit diminution of velocity (or per atm-cm path length). Unfortunately for the present there is no experimental data on Fnn' determination directly from proton beam in upper atmospheric constituents in the whole region from 0,2 to at least [illegible] kev. The excitation of hydrogen emissions was theoretically calculated by the equations of statistical equilibrium and ionization equilibrium (look 3[illegible]) with the use of the effective cross-sections calculated by Bates and his associates (35,36) for proton beam in atomic hydrogen and also with experimentally obtained data for protons in azot, oxygen and air. The resulting curve for Fnn' (v) has broad maximum for H_α at the velocity of about 2000 km/sec (E~20 kev) and sharp decrease with the diminution of velocity to ~1000 km/sec (~5kev).

The form of the $F_{nn'}$ (v) dependence may be evaluated in another way also. Suppose that proton is incident on atmosphere of pure N_2.

Experimental data on number of capture and loss cycles in a hydrogen beam in function of energy $\frac{dN_c}{dE}$ in azote are given in (33). The ratio of captures on the 3^{rd} quantum level to all captures for energies of 1 - 4 kev has been measured (37), and is close to theoretical values for $H + H^+$ (35) for such energies. So for $E > 5$ kev this ratio may be taken from (35). Such calculation gives the $F_{nn'}$ (v) curve only from capture from N_2 on the 3^d level (it seems that atmospheric gas mixture will not change this result significantly) with a broad maximum at $E = 30$kev and the total number C (where $C = \int_0^{v_0} F_{nn'}(v)\,dv$) equal to $76 H_\alpha$ quanta per incident proton of energy $E > 300$ kev. Analogous estimates of the position of the maximum of $F_{nn'}$ curve can be made by the use of adiabatic criterion of Massey, though validity of such estimates for excitation processes apparently have not been proved.

In short, all the data which use the excitation probabilities by capture to excited state from (34) lead to sharp decrease of excitation efficiency at low energies ($E < 10$ kev). But the absence of direct experimental measurements especially with atomic oxygen make this most important point somewhat uncertain.

2.2. The role of protons in auroral excitation

As has been calculated (for example see Chamberlain (34)) for pure proton beam with the above mentioned $F_{nn'}$ function the quantum intensity ratio $Q(H_\beta)/Q(3914)^{x} > 0{,}3$ for initial proton energies $E < 100$ kev and this ratio rises with the diminution of

x) Q (3914) is the quantum intensity of (0,0) band 1NGN_2^+ per cm^2 per sec, Q (4709) is the same for (0,2) band.

initial proton energy. Taking Q (3914)/Q(4709)=17,5 (34) we have Q (H_β)/Q(4709)>5.... As described above even in usual hydrogen field this ratio is about unity (29) and only in some cases (20, 23, 30) values much more than unity were registered. This means that even in usual hydrogen field the main (at least comparable) part of luminocity of atmospheric gases apparently is excited by electrons and pure proton bombardment is very rare case, possibly connected with protons of especially low velocities (23).

2.3. Proton flux anisotropy

Another important characteristic of proton influx is the pitch-angle distribution function $N(\theta)$ ($cm^{-2}sec^{-1}ster^{-1}$). Using $N(\theta)$ (supposing it is independent of velocity) and Fmn' (v) the formulae for the line profiles in magnetic zenith, magnetic horizon and intermediate directions may be derived (34, 38, 39). It is evident from symmetry considerations that for isotropic proton flux for $\theta<90^\circ$ per unit solid angle on a unit square perpendicular to magnetic force line $N(\theta)$ = const (or $\eta(\theta)\cos\theta$ =const, where $\eta(\theta)$ is the particle intensity) the form of magnetic zenith and magnetic horizon profiles coincide (in the intermediate directions a slight asymmetry will conserve). Therefore the fact that typical observed profiles in these two directions are markedly different means that irrespective of initial proton energy spectrum the beam is anisotropic significantly. Quantitative estimates of the $N(\theta)$ function approximated by the form $N(\theta) = K\cos^{n+1}\theta$ show that observed profiles lead to $-1 \leq n \leq 3$. This may be compared with nearly isotropic particle intensity $\eta(\theta)$ measured from rocket (31), that is $n \neq 0$, for $E > 160$ kev.

2.4. Proton energy spectrum

As we have no experimental justification that proton flux anisotropy is independent of energy in the region $E < 100$ kev we cannot be sure that the full distribution function of proton beam $N(v_0/\theta)$ permit the separation of variables but such supposition is usually made. Both Fnn' (v) and $N(\theta)$ functions are needed for derivation of $\Psi(v_0)dv_0$ — the velocity dependent part of distribution function. Assuming the abovementioned form for Fnn' (v) and $N(\theta)$ and taking $\Psi(v_0)dv_0$ = const $v_0^{-s} dv_0$ to a sharp cutoff at some minimum velocity v_{min} Chamberlain (34) shown that for $v > v_{min}$ observational profiles lead to $2 \leq s \leq 3$ in the energy region of order 10 ÷ 1 kev. So compromise distribution function may be written as

$$N(v_0|\theta)\, dv_0\, d\theta = const \cdot \cos\theta \cdot v_0^{-2.5} dv_0\, d\theta$$

For energies E>100 kev the energy spectrum is much more steep (31, 32) and variable. The energy range 5 ÷ 150 kev for the present apparently has not been studied by any method. However some estimates could be made from comparison of simultaneous rocket and ground observations (32) if the registered H_β profile was published. Supposing that the profile was of typical form, it can be evaluated that as much as $3 \cdot 10^5$ ions/cm^{2}sec ster with $E > 20$ kev might penetrate to auroral heights at the moment of the experiment without being noticed by profile observations. This is only about 3 times lower than extrapolation used in (32) gives. But for lower energies of order of 1 kev the flux must exceed significantly that extrapolated in (32).

3. Discussion

This last conclusion as other interpretation problems for example, angular distribution, the presence of electron bombardment in hydrogen field and so on depend on assumed form of Fnn' (v) function. It must be mentioned that sharp low energy cutoff in this function appear only because theoretical calculations for $H^{+}+H$ collisions (35) are applied to upper atmospheric conditions. If for atmospheric gaz mixture the ratio of captures to an excited state to all captures by proton does not vary so sharply in the region 5 ÷ 15 kev as the results of (35) imply the maximum of Fnn' curve (see 34) may shift significantly to lower energies. If our present knowledge (34) on the form and absolute values of Fnn' is completely wrong the scope of observational data for the present (21, 25, 31, 32) cannot exclude possibility that typical hydrogen field emission is caused by protons of energies of tens of kev.

In any case the maximum of proton differential energy spectrum must lay in the region 1 ÷ 30 kev. The hydrogen emission problem now may be analysed from different sides. The height of maximum luminocity, the hydrogen emission cross sections in the region mentioned above and especially direct experiment on proton injection or proton registration in the upper atmosphere would be decisive. The systematic search for hydrogen emission profile variations and $Q(H_\beta)/Q(\lambda 3914)$ ratio also may lead to important information on proton bombardment.

The following aspects of incident proton beam cannot escape attention. Firstly, the position of maximum proton differential energy spectrum is similar within an order of magnitude to one of auroral electron spectrum and it is hardly a fortuitous coincidence. Secondly, proton spectrum in comparison to auroral electron one typically has long high energy tail up to some hundreds of kev which possibly signifies to acceleration of protons in the upper atmosphere by some analogy to Fermi acceleration(for example by hydromagnetic waves) and not by electric field. It is clear that the wide energy spectrum and systematic geographical picture of proton bombardment is in harmony with the idea of their local acceleration in the upper atmosphere but not with their penetration to auroral heights directly from solar stream.

The discovery of sistematic picture of proton bombardment means that the sense of the notion "aurora" must be precised as low energy particle bombardment of upper atmosphere but not only distinct easily visible bright formations. Usual all-sky and other auroral morphology studies deal not with aurora in general but only with bright electron aurora while proton aurora with its low emission intensity is a distinct and remarkable upper atmospheric phenomenon completing the picture of upper atmospheric disturbance. It is especially important for general auroral theory.

References

I. L. Vegard. Nature, II4, I089 (I939)

2. L. Vegard. C.R. Acad.Sci.,230, I884 (I950)

3. L. Vegard. Geofys.Publ. Oslo, I8, No.5 (I955)

4. C.W. Gartlein. Trans.Amer.Geophys.Un., 3I,I8 (I950)

5. L. Vegard. Geofys.Publ., Oslo, I9, No.9 (I956)

6. A.B. Meinel. Astrophys.J., II3, 50 (I95I)

7. A.B. Meinel. Mém.Soc.Roy.Sci. Liège, I2, 203 (I952)

8. C.W. Gartlein. Phys.Rev., 8I, 463 (I95I)

9. Yu.I. Galperin. Report at V CSAGI, I958; Planet.Sp.Sci., I, 57 (I959).

I0. L.S. Evlashin. Geomagnetism and Aeronomy, USSR, I,54 (I96I)

II. O.L. Vaisberg, Coll. "Aurorae and Airglow" , No.8, 36 (I962) Results of IGY, Publ.by USSR Acad.Sci.

I2. M.H. Rees, A.E. Belon and G.J. Romick. Planet.Space Sci., 5, 87 (I96I)

I3. A. Omholt, W. Stoffregen and H.Derblom. J.Atm.Terr.Phys., 24, 203 (I962)

I4. V.I. Krassovsky. Uspekhi Fiz.Nauk, USSR., 75, 501 (1961).

I5. C.W. Gartlein. Mém.Soc.Roy.Sci., Liège, I2, I95 (I952)

I6. R. Montalbetti and A. Vallance Jones. J.Atmos.Terr.Phys, II, 43 (I957)

I7. C.Y. Fan and D.H. Schulte. Astrophys.J., I20, 563 (I954)

I8. A. Omholt. J.Atmos.Terr.Phys., I0, 320 (I957)

I9. A. Omholt. Geofys.Publ., Oslo, 20, No.II (I959)

20. G.J. Romick and C.T. Elvey. J. Atmos.Terr.Phys., I2, 283 (I958)

2I. M.H. Rees. Mém.Soc.Roy.Sci., Liège, 5, v.4,f.I, 609 (I96I)

22. J.M. Malville. Planet.Space Sci., 2, I30 (I960)
23. R. Montalbetti. J.Atmos.Terr.Phys., I4, 200 (I959)
24. P.Y. Sukhoivanenko. Coll. "Aurorae and Airglow", No.7, 7 (I96I), Results of IGY Publ.by the USSR Acad.Sci.
25. Yu.I. Galperin, O.T. Yurchenko. Coll."Aurorae and Airglow" No.9 (I962), Results of IGY, Publ.by USSR Acad.Sci.
26. F.K. Shuiskaya. Astron.Zhurn., USSR, 37, I86 (I960)
27. C.S. Deehr. Univers.Of Alaska (I96I), preprint.
28. V.I. Ivanchuck. Coll. "Results of IGY" Kiev University Press I, 58 (I96I)
29. O.L. Vaisberg. Coll. "Aurorae and Airglow" No.8 (I962), Results of IGY, Publ.by USSR Acad.Sci.
30. D.M. Hunten. J. Atmos.Terr.Phys., 7, I4I (I955)
3I. L.R. Davis, O.E. Berg and L.H. Meredith. Proc.of the First Internat.Space Sci.Symp., Nice, I960, p.72I, Ed.by H. Kallmann Bijl, North-Holland Publ.Comp.
32. C. Mc.Ilwain. J.Geophys.Res., 65, 2727 (I960)
33. S.K. Allison. Rev.Modern Phys., 30, II37 (I958)
34. J.W. Chamberlain. Physics of the Aurora and Airglow. New York, London, Acad.Press (I96I)
35. D.R. Bates and A. Dalgarno. J.Atmos.Terr.Phys., 5, 329(I954)
36. D.R. Bates and G.Griffing. J.Atmos.Terr.Phys., 3, 2I2 (I953)
37. N.P. Carleton, T.R.Lawrence. Phys.Rev., I09, II59 (I958)
38. A. Omholt. J.Atmos.Terr.Phys. 9; I3 (I956)
39. Yu.I. Galperin. Astron.Zhurn., USSR, 35, 382 (1958)

HELIUM IN THE UPPER ATMOSPHERE

N.N.Shefov
Institute of Physics of the Atmosphere
U.S.S.R. Academy of Sciences
Moscow

Summary

The paper deals with the excitation of helium emission in the upper atmosphere. Emission of λ 10830 Å is observed only in sunlit atmosphere and appears due to fluorescence. The excitation of helium emission, λ 10830 Å, essentlially depends on ultra-violet solar radiation with $\lambda < 304$ Å and λ 584 Å. The paper examines varieties of this radiation.

During the IGY and in the period that followed the Institute of Physics of the Atmosphere of the U.S.S.R. Academy of Sciences has been engaged in research into the problem of the upper atmosphere emission. Displays of twilight enhancement of λ 10830 Å helium and λ 8446 Å oxygen emission were undoubtedly among the most interesting phenomena we had occasion to detect. The oxygen line of λ 8446 Å was observed at Zvenigorod during long summer twilights with an exposure of about two hours in unperturbed magnetic conditions (1).

The existence of this emission which appears in twilight as a result of absorption of the L_β solar line by atomic oxygen was predicted by Shklovsky (2). The mean measured intensity of λ8446 Å emission was estimated at 13 Rayleighs. This intensity is lower by one order of magnitude than the intensity estimated by Shklovsky and by one order higher than the intensity calculated by Brandt (3).

For all that, the detection of helium emission, λ10830 Å, remains the most interesting feature. Helium was long ago known to exist in the atmosphere, but its content in the upper atmosphere, beginning from the first computations made by Jeans (4) and until recently (5-8) could be determined only by purely theoretical calculations and on the basis of different assumptions of its origin in the terrestrial atmosphere. Many attempts have been made to discover helium lines in the visible region of the spectrum of aurorae and all of them have failed. It was not until image converters came into use that it became possible to observe helium emission, λ10830 Å, for the first time in an aurora on February 10-11, 1958 (Mironov et al.) (12,13). Later, Fedorova (14,15) who made systematic observations of aurorae discovered new evidence in support of this phenomenon.

A twilight enhancement of helium emission λ10830 Å in the absence of aurora was observed by the author with the help of a spectrograph (16-19) and by Shcheglov who used a Fabry-Perot étalon (17-21). We have also succeeded in recording helium emission during the solar eclipse on February 15, 1961, when observations were conducted from an aircraft (Shuiskaja) (22).

Unfortunately, information on the observations of λ5875 Å helium emission (23,24) apparently leaves out of account the blending effect exerted on λ5875 Å R emission by the hydroxyl band branch (8,2). According to Fedorova (25), the intensity of helium emission λ10830 Å in sunlit aurora shows a certain connection with the solar activity.

We know that helium emission of λ10830 Å is observed only when the sun illumines the upper layers of the atmosphere both during aurorae and in ordinary twilight with absens of aurorae. In this case the intensity of the "resonance" line, λ10830 Å, is rather high while the intensities of the subordinate lines are so negligible that nobody can so far claim to have discovered them authentically. All this undoubtly indicates to the fact that helium emission of λ10830 Å can be caused only by a resonance fluorescence of helium atoms in the 2^3S metastable state in solar radiation (26-28).

The process of excitation of λ10830 Å emission by helium atoms with an energy of about 256 kev was examined by Malville (23). The value of the relationship of the λ10830 Å and λ5875 Å line intensities he has calculated (0.09) disagrees with the observation data because λ5875 Å emission has never been registered for certain. According to the computed value (0.09), its intensity may reach several thousand Rayleighs in aurorae. However, even if the emission of $\lambda 5875$ Å was present in the aurora on February 10-11, 1958, its intensity could not be over 10 Rayleighs as it follows from the published spectra (12), whereas the intensity of $\lambda 10830$ Å is very high. Besides, the helium emission of $\lambda 10830$ Å should have been present also in the atmosphere which was not illuminated by the sun which was not the case. For this reason, the role of the process of helium excitation examined by Malville must be very insignificant.

The lifetime of the 2^3P excited state initiating the radiation of the $\lambda 10830$ Å line may be determined only by the probability of a spontaneous transition to the 2^3S state. Therefore, the number of transitions $2^3S - 2^3P$ due to radiation absorption should equal the number of transitions $2^3P - 2^3S$ with the radiation of the $\lambda 10830$ Å line (Table 1). The intensity of the emission $\lambda 10830$ Å in twilight amounts to about 1,000 Rayleighs while in aurora it can reach several tens of kilorayleighs. This is in good agreement with the population in the 2^3S helium metastable level having from one to several tens of metastable atoms per cubic centimetre.

Examination of the entire combination of the processes causing the excitation of the metastable state of helium, 2^3S, has shown that the priority belongs to the following two processes: excitation by electrons with an energy of about 25 ev and excitation due to solar radiation in $\lambda 584$ Å and λ537 Å lines of helium. Electrons with an energy of about 25 ev may appear in the upper atmosphere as a result of the ionisation of atmospheric atoms and molecules by electrons with an energy of about 10 kev and the ultra-violet solar radiation with $\lambda < 304$ Å (29,30). Electrons with an energy of about 10 kev have been already discovered by means of rockets and artificial satellites (31-36). The intensity of the ultra-violet solar radiation has been likewise repeatedly determined with the help of rockets (37-38).

A system of steady-state equations has been devised for computing the intensities of various helium lines. The calculations involved only the first five excitation levels of orthohelium and parahelium. The effective excitation cross-section of the 2^3S metastable level by electrons with with an energy of about 25 ev was taken from Schultz's data (39) and for the other levels from Allen (40) and Yakhontova (41). Exchange transitions of helium atoms from the 2^1S state to the 2^3S state possess a large effective cross-section during collisions with ordinary "thermal" electrons. Kondratiev (42) and Smith and Muschlitz (43) estimate this effective cross-section at $\sim 3.10^{-14}cm^2$. This inadvertently promotes the role of the resonance excitation, by solar radiation in the λ584 Å and λ537 Å lines, of the parahelium levels, 2^1P and 3^1P, from which the helium atoms can be transferred with radiation to the 2^1S level. Exchange transitions between higher singlet and triplet states of helium during collisions with electrons and helium atoms in the ground state also have large effective cross - -sections. These processes have been studied by Lin and Fowler (44) and John and Fowler (45). However, the n^1P levels are less populated in condition of the terrestrial atmosphere. For this reason, the role of exchange transitions from all parahelium levels, except for 2^1S, will be negligible. Incidentally, this is confirmed by the absence of λ 5875 Å emission.

The solution of the system of steady-state equations has yielded for helium the dependence of the population of the 2^3P level and, hence also the intensity of the λ 10830 Å emission, upon the content of electrons with an energy of about 25 ev in the upper atmosphere and the intensity of the ultra-violet solar radiation (18, 19, 46) (Table 2).

The functions φ, ξ and ψ describe, respectively, the role of the processes of excitation by electrons with an energy of about 25 ev and the processes of recombination and ultra-violet solar radiation in λ 584 Å and λ 537 Å. Since the degree of helium ionisation up to 2,000 km is of the order of 10^{-3} (47-49) and the electron density is close to 10^4 cm^{-3} the effect of the recombination processes can be frequently neglected. The function ψ which determines the role of the ultra-violet solar radiation is directly proportional to the intensity of the λ 584 Å and λ 537 Å lines when the concentration of ordinary "thermal" electrons exceeds $10^2 cm^{-3}$. The functions φ and ψ also depend on the electron concentration and the temperature in the upper atmosphere which are the factors determining the effect of the processes of electron exchange when parahelium passes into orthohelium.

However, the transparency of the terrestrial atmosphere differs in the wavelengths $\lambda 584$ Å and $\lambda < 304$ Å. Absorption in the wavelengths $\lambda < 304$ Å, and also in $\lambda 584$ Å far from the centre of the line, will be brought about by the photo-ionisation of oxygen atoms and nitrogen molecules. The heights of layers, which correspond to an optical thickness equal to unity, in the wavelengths $\lambda 584$ Å and $\lambda < 304$ Å will be 350 km and 300 km, respectively, at an oblique incidence of rays. The heights corresponding to a ten-fold attenuation are estimated at 300 and 250 km. The effective values of photo-ionisation cross-sections were taken from Dalgarno and Parkinson (50). In the centre of the $\lambda 584$ Å line the absorption will be also effected by helium atoms. Inasmuch as the absorption coefficient at $T \sim 1500^{\circ}K$ is about $10^{-13} cm^2$ (51,52) the atmospheric layer will be optically thick when the sun rays fall oblique. It is extremely difficult to solve the problem of the diffusion of resonance radiation in an optically thick medium for a spherical atmosphere in the case of almost pure scattering--this problem still awaits its solution. For a plane - parallel medium the problem was investigated for some limiting cases by Ambartsumyan (53), Sobolev (54) and Chandrasekhar (55). Brandt examined only the diffuse reflection of radiation $\lambda 584$ Å (56). It stands to reason, however, that the role of λ584 Å and λ537 Å emissions in the excitation of the 2^3S helium metastable state will be quite impressive at the heights of 1,000 km and more. At lower heights the helium atoms will be excited by electrons with an energy of about 25 ev which appear during photoionisation by solar radiation with $\lambda<304$ Å (46). It should be noted in this connection that the role of λ584 Å radiation evaluated earlier (18,19) was apparently somewhat exaggerated. However, to arrive at the final solution the problem of the diffusion of λ584 Å radiation should be studied in greater detail.

We have pointed out elsewhere that the presence of helium in the terrestrial atmosphere was known long ago. The study of the earth's satellites acceleration (57) made it possible to specify more accurately the data of atmospheric density (58), which were obtained on the basis of the helium dissipation theory. Observations of helium emission, λ10830 Å, yield almost identical results. However, the following is far more important. As has been shown, ultra--violet solar radiation is an essential factor in the processes of excitation of λ10830 Å helium emission. For this reason, the investigation of the emission, λ10830 Å, allows ordinary ground observations of solar radiation with λ584 Å and $\lambda<304$ Å to be undertaken.

The problem of variations in the ultra-violet solar radiation is not yet completely solved both from an experimental and theoretical points of view. Analysis of the data provided by rocket research, including L_α spectroheliograms, leads us to the following conclusions (59).

1. The temperature of the effective radiation layer is of the order of $20000^{\circ}K$.

2. The temperature in the active and unperturbed regions of the sun is almost the same.

3. The density in the active regions is approximately by less than an order of magnitude higher than in the quiet regions.

4. The total solar radiation flux in the L_{α} line can change negligibly (by two or three times) during the entire cycle of solar activity.

These assumptions concerning the nature of the active regions agree generally with the model of the chromosphere devised by Ivanov-Kholodny and Nikolsky (60). It follows therefore that if the radiation of the HeI λ584 Å and apparently HeII λ304 Å which forms, like L_{α}, in an optically thick layer, arises in the same cases as L_{α}, then the variations of the intensity of these lines should be of the same order of magnitude as for L_{α}. The same is true of L_{β}. For this reason the active formations on spectroheliograms in the helium lines may be expected to vary 5-10 times. Hence, the variation of the total radiation flux should be on an average 2 to 3 times even if the area of active formations proves greater than that observed on L_{α} spectroheliograms.

Matters appear quite different as regards the study of the sun in the region with $\lambda < 300$ Å. The lines in this spectrum region arise in an optically thin layer (52).

Since the intensity of the lines in this case is proportional to the square of the electron density the local brightness of the disturbed areas on the sun in these lines may be higher by two orders of magnitude than in quiet areas. Therefore, the total radiation flux with $\lambda < 30$[illegible] Å can vary less than an order On the basis of these data it can apparently be expected that solar radiation will be correlated with the area of the faculae (59).

In this way, taking into account the anticipated variations of the ultra-violet solar radiation, it can be assumed that in aurora electrons with an energy of about 10 kev and a solar radiation with $\lambda < 304$ Å can make a commensurable contribution to the formation of electrons with an energy of about 25 ev. During ordinary twilight and by day under quiet conditions the ultra-violet solar radiation with $\lambda < 304$ Å will apparently make a decisive contribution to the intensity of the λ 10830 Å emission.

The author is indebted to Professor V.I.Krassovsky for his valuable advise and constant interest throughout the problem.

References

1. N.N.Shefov.Coll. "Aurorae and Airglow", No.9, 55 (1962) Results of IGY, Published by the USSR Academy of Sciences.
2. I.S.Shklovsky. Astron.Zhur. USSR, 34, 127 (1957)
3. J.C.Brandt. Astrophys. J., 130, 228 (1959)
4. J.H.Jeans. The Dynamic Theory of Gases, 4th ed., Cambridge, 1925.
5. D.R.Bates and M.R.C.McDowell, J.Atm.Terr.Phys., 11, 200 (1957).
6. I.S.Shklovsky.Astron.Zhurn.USSR, 35, 557 (1958)
7. E.K.Byutner.Astron.Zhur.USSR, 36, 89 (1959)
8. D.R.Bates and M.R.C.McDowell. J.Atm.Terr.Phys., 16, 393 (1959)
9. M.R.Bernard.C.R.Acad.Sci. 225, 352 (1947)
10. D.Barbier and D.R.Williams. J.Geophys.Res., 55, 401 (1950)
11. A.Dauvillier. IV. Le magnetisme des corps célestres, t. III.Les Aurores polaires et la luminiscence nocturne, Paris, 1954.
12. A.V.Mironov, V.S.Prokudina and N.N.Shefov.Coll."Spectral, Electrophotometrical and Radar Researches of Aurorae and Airglow", No 1, 20 (1959). Results of IGY, Published by the USSR Academy of Sciences.
13. V.I.Krassovsky and G.I.Galperin. Transactions of the IAU, v.X. Xth General Assembly held at Moscow 12-20 August 1958, p.327. Cambridge Univ.Press, (1960).
14. N.I.Fedorova.Planet. Space Sci., 5, 75 (1961)

15. N.I.Fedorova. Coll."Spectral, Electrophotometrical and Radar Researches of Aurorae and Airglow", No.5, 44 (1961). Results of IGY,Published by the USSR Academy of Sciences.

16. N.N.Shefov. Astron.Cirk., Published by the USSR Academy of Sciences, No.222, 11 (1961)

17. V.I.Krassovskii.Planet.Space Sci., 8, 125 (1961)

18. N.N.Shefov.Ann.Géophys.,17, 395 '1961)

19. N.N.Shefov. Coll. "Aurorae and Airglow", No.8, 50 (1962) Results of IGY,Published by the USSR Academy of Sciences.

20. P.V.Shcheglov. Astron. Zhur.USSR, 39, 158 (1962).

21. P.V. Shcheglov, Coll. "Aurorae and Airglow", No.9, 59 (1962). Results of IGY,Published by the USSR Academy of Sciences.

22. F.K.Shuiskaya.Coll. "Aurorae and Airglow", No.10,(1962) Results of IGY,Published by the USSR Academy of Sciences.

23. J.M.Malville. J.Atm.Terr.Phys., 21, 54 (1961)

24. V.I.Ivanchuk and P.Y.Sukhoivanenko. Information Bulletin, No.3, 35 (1961),Organising Committee of IGY of the Academy of Sciences of the Ukrainian SSR,Published by the Ukrainian Academy of Sciences,Kiev.

25. N.I.Fedorova. Izv.Akad.Nauk USSR,ser.geofiz,No.5, 661 (1962)

26. V.I. Krassovsky.Proc. XIth Intern.Austronautical Congr., Stockholm, 518 (1960)

27. N.N.Shefov.Planet.Space Sci.,5, 75 (1961)

28. N.N.Shefov.Coll. "Spectral,Electrophotometrical and Radar Researches of Aurorae and Airglow," No.5, 49 (1961) Results of IGY,Published by the USSR Academy of Sciences.
29. W.B.Hanson and F.S. Johnson. Les spectres des astres dans l'ultraviolet lointain, 390 Belgique, (1961)
30. I.S.Shklovsky. Usp.fis.nauk,USSR,75,351 (1961)
31. V.I.Krassovsky, Y.M.Kushnir,G.A.Bordovsky, G.F.Zakharov and E.M.Svetlitsky.Report to IGY Assembly in Moscow,1958. Isk.Sput.Zemli,USSR Acad.Sci., No.2, 59 (1958)
32. V.I.Krassovsky, I.S.Shklovsky, Iu.I.Galperin and E.M. Svetlitsky. Dokl.Akad.Nauk SSSR,127, 78 (1959)
33. V.I.Krassovsky, I.S.Shklovsky,Iu.I.Galperin and E.M.Svetlitsky. Isv.Akad.Nauk SSSR,ser.geofiz., No.8, 157 (1959)
34. C.E.McIlwain, J.Geophys.Res., 65, 2727 (1960)
35. I.A.Savenko, P.I.Shavrin and N.F.Pisarenko.Geomagnetism and Aeronomy, USSR Acad.Sci. 1, 875 (1961)
36. B.J.O'Brien, C.D.Laugnin, J.A.Van Allen and L.A.Frank. Preprint,January (1962).
37. H.E.Hinteregger. J.Geophys.Res.,66, 2367 (1961)
38. A.V.Bruns and V.K.Prokofiev.Isk.Sput.Zemli, USSR Acad. Sci. No 11, 15 (1961)
39. C.J.Schulz.Phys.Rev.,116, 1141 (1959)
40. K.U.Allen.Astrophysical Quantities. London,Atlone Press (1955)
41. V.E.Yakhontova. Izv. Akad.Nauk SSSR,ser.fiz., 24, (1960)
42. V.N.Kondratiev.Structure of Atoms and Molecules, ed.2, USSR Acad.Sci.,Moscow (1959)

43. G.M.Smith and E.E.Muschlitz,J.Chem.Phys, 33, 1819 (1960)

44. C.C.Lin and R.Fowler. Ann.of Phys.,15,461 (1961)

45. R.M.St.John and R.G.Fowler.Phys.Rev.,122, 1313 (1961)

46. N.N.Shefov.Ann.Géophys.,18, 105 (1962)

47. L.C.Hale.J.Geophys.Res.,66, 1554 (1961)

48. W.B.Hanson.J. Geophys.Res.,67, 183 (1962)

49. R.E. Bourdeau, E.C.Whipple, J.L.Donley and S.J.Bauer. J.Geophys.Res.,67, 467 (1962)

50. A.Dalgarno and D.Parkinson. J. Atm.Terr.Phys., 18, 335 (1960)

51. R.G.Athay and H.R.Johnson.Astrophys.J., 131, 413 (1960)

52. E.V.Kononovich.Astron.Zhur.USSR, 38, 218 (1961)

53. V.A. Ambartsumyan, E.R.Mustel, A.B.Severny and V.V. Sobolev. Theoretical Astrophysics,Gostekhizdat,Moscow (1952)

54. V.V.Sobolev. Transfer of Radiant Energy in the Stellar and Planetary Atmospheres,Gostekhizdat,Moscow (1956)

55. S.Chandrasekhar.Radiative Transfer,Oxford (1950)

56. J.C.Brandt. Astrophys.J., 134, 975 (1961)

57. P.E.Zadunaisky, I.I.Shapiro and H.M.Jones.Res.Space Sci., Smiths.Astroph.Obs.Special Rep.,61 (1961)

58. M.Nicolet. J.Geophys.Res.,66, 2263 (1961)

59. E.V.Kononovich and N.N.Shefov.Astron.Zhur.USSR, 39,(1962)

60. G.S.Ivanov-Kholodny and G.M.Nikolsky.Astron.Zhur.USSR, 38, 45 (1961)

Table I

$$n_{2^3S} \cdot w \rho B = A \cdot n_{2^3P}$$

$$I = A \cdot n_{2^3P} \cdot H_{He}$$

$$n_{2^3S} = \frac{I}{w \rho B \cdot H_{He}}$$

w — dilution factor,

A, B — Einstein transition values,

ρ — density of λ 10830 Å solar radiation,

H_{He} — height of homogeneous atmosphere for helium,

I — λ 10830 Å line intensity in quanta

Table 2

$$\frac{n_{2^3P}}{n_o} = F\left(1 - \frac{n^+}{n_o}\right)\varphi + \frac{n^+}{n_o}\xi + \left(1 - \frac{n^+}{n_o}\right)\psi$$

n_o --- full concentration of helium,

n^+ --- concentration of He^+ ions,

F --- flux of electrons with an energy of about 25 ev.

TEMPERATURE AND CORPUSCULAR HEATING IN AURORAL ZONE

T.M.Mulyarchik, P.V.Shcheglov
Institute of Physics of the Atmosphere
USSR Academy of Sciences, Moscow

Summary

Results of the observations of the temperature of the polar atmosphere and some possible mechanisms of its heating are discussed.

The upper atmosphere can be heated by the ultra-violet radiation of the sun, corpuscular streams, hydromagnetic waves. A number of measurements (1-4) shows that at altitudes of 100-200 km the temperature of the night atmosphere is higher in the auroral zone than in the middle latitudes. One can believe that the latitude effect is caused by the corpuscular heating which takes place mainly in the polar atmosphere.

Let us consider temperature measurements at the atmosphere in the auroral zone.

The most ordinary are the ground observations : interferometric estimates, permitting to determine Doppler temperature from the contours of emission lines and spectroscopic measurements of the rotational temperature of molecular bands. One should be sure that the temperatures in such a way obtained coincide with the kinetic temperature of the medium. So either the mechanism of excitation of the observed emission should not disturb the Maxwell distribution or there should pass enough time between the excitation and de-excitation (fluorescence) so that the atom should undergo some collisions and Maxwell distribution could be restored. When observing forbidden lines λ 5577 and λ 6300 the latter condition is fullfilled up to the heights of 150-300 km accordingly. (Apparently the most probable mechanism of excitation λ 5577 and λ 6300 is an electronic impact, so Maxwell distribution remains at higher altitude as well). In the conditions of the upper atmosphere the natural width of spectral lines and collisional broadening are negligible in comparison with Doppler broadening. Turbulent motions can be apparently also neglected, so the contour of the line is determined only by thermal movements and permits to judge of the kinetic temperature of the medium.

It is most convenient to measure rotational temperatures during aurorae from bands (0,0) and (0,1) 1NG N_2^+. These are permitted bands, so if the mechanism of excitation results in deflection of populations of the rotational levels from Boltzmann distribution it will not recover till the moment of de-excitation. But as 1NGN_2^+ is apparently excited by electronic impact when the energy of the molecule is not changed one can hope that the equilibrium with the atmosphere is not disturbed. Laboratory tests showed that the proton excitation apparently also does not change the angular moment. Thus the rotational temperature determined from the bands 1NG N_2^+ should coincide with the kinetic temperature of the medium.

Spectroscopic measurements of the temperature of aurorae enable to obtain temperatures mainly of the altitudes of 80-150 km (usual forms of aurorae), more seldom ~ 200 km (red aurorae of the A type) and still more seldom for the higher altitudes sunlit aurorae). These measurements should be accompanied by the determination of the height of the radiant region. Unfortunately, this was not always done at all, so one can often judge of the height of the layer for which the temperature is determined only by the form of the light observed. A detailed survey and discussion of the obtained rotational temperatures are given by Hunten (5).

The temperature values for which heights are known fall well enough on the temperature curve of the 1961 CIRA model (6). This model is referred to the middle latitudes, so the measurements do not show any temperature rise in the direction of high latitudes. However for the given altitudes the effect cannot be great and it can be easily hidden by the erros of determination of the temperature and altitude. In general it is very difficult to notice any temperature change at the altitudes of 100 - - 150 km depending on the intensity of the aurora, as the gradient at these altitudes is great and it is difficult to separate temperature changes with the height of the heating effects during the aurora. (The temperature changes twice at the altitude of the order of 25 km). The condition is better for the altitude of 200 km, as from this level the temperature gradient decreases and temperature changes are difficult to be attributed to the change of the altitude even if these altitudes are not accurately determined. So the determinations of the rotational temperatures of 1NG N_2^+ in the red aurorae of the type and especially in the sunlit aurorae and also interferometric observations of λ 6300 which comes from the altitude of 200 km. Rotational temperatures in the sunlit aurorae are within the limits of 800-2300°K (7-10). The fact that they are over a wide interval, allows to think that these temperatures reflect real conditions and do not depend on the mechanism of excitation. According to Störmer sunlit rays are observed at the altitudes of 400-500 km. The temperature of the normal atmosphere in these conditions, according to (6), does not exceed 1800°K.

Observations of the red line profiles (4) show that the Doppler temperature can change from 1200°K in the night almost without aurora to 3500°K for the bright red aurorae. Figs. 1-4 present the interferograms of the line of the laboratory source and λ 5577 and λ 6300 for different aurorae. There were no simultaneous measurements of the altitudes carried out, however the growth of intensity of the [illegible] with the growth of temperature shows that the temperature rise is hardly connected with the growth of altitude of the luminous formation.

It should be noted that sometimes interferometrically (T.M.Malyarchik) a non-Doppler profile of λ 6300 was observed, the intensity in the wings of the observed contour being greater than for the Doppler contour. This permits to suppose that there are some cases of superimposing of higher temperature contour of less intensity on the basic contour. However for the observations on the 17-th of December, 1958, when the temperature of 3500°K was registered the contour did not differ from Doppler distribution. At the same time with a slight difference of the temperatures of the radiant regions the resulting contour of the emission line proves to be close to Doppler contour.

As it is difficult to conceive such a night temperature at these altitudes within the bounds of the exciting models of the atmosphere one should admit the fact of intense heating of the atmosphere during aurorae.

Besides such a temperature rise of the polar atmosphere during some separate days for aurorae forms, a systematic rise of Doppler and rotational temperatures in the auroral zone is observed. The effect is not great but it can be traced by interferometric measurements of green and red lines (3,4) and determinations of the rotational temperature of OH (1,2) in the nightglow. (It is true that nothing is known of the variations of the height of the glow of these emissions).

The most attractive variant of polar atmosphere heating is warming up by corpuscles. Optical observations of the nightglow of the polar sky and aurorae as well as rocket measurements of corpuscular streams permit to make estimates of the quantity of energy (entering) in the polar atmosphere.

There exist other possible mechanisms of polar atmosphere heating. In the first place we mean magnetic-hydrodynamic waves (11). If the mean amplitude of these waves over the ionosphere reaches some hundreds of gammas at frequencies of 0.1 - 10 herts, the dissipation of the energy of similar waves at the height of 200-300 km can prove to be essential for the heat balance of the atmosphere. It may be that such conditions take place during magnetic storms (12). Magneto - hydrodynamic waves with lower frequencies (periods 4-8 min) and amplitude of the order of $10^2 \gamma$ are discovered during ground observations (13). One can suppose that there exist such waves of higher frequency. It is necessary to study quick variations of the magnetic field at high altitudes and on ground to provide the material for confirmation of this supposition.

Other sources of heating, (meteors, acoustic waves from the troposphere etc.) are not significant in the heat balance of the polar atmosphere (14).

It is difficult to determine the amount of the energy of the corpuscular stream changing to heat during its interaction with the atmosphere. Various estimates (15,16) differ from each other, but, apparently, the greater part of the energy reradiates in the form of electromagnetic energy (emission in the visible, infrared and especially far ultraviolet region of the spectrum).

We assume the amount of the electron energy changing to heat to be equal to 20%. Direct measurements of electron fluxes during a weak (apparently, IBCI) and strong (IBCIII) aurora gave values of the order of 1-2 and several hundred erg.cm^{-2}sec^{-1}. sterad^{-1} (17). No rocket measurements in polar areas take place without aurorae. Electron fluxes in this case can be estimated according to optic observations of the bands λ 3914 and λ 4278 1NGN$_2^+$ (15). For soft electrons the energy lost to form one ion-pair is equal to 35 electronvolts (18). At the same time 2% of the formed ions radiate in the band of (0,1) 1NGN$_2^+$ (19,20). Apparently, electron current S equals to

$$S_{erg} = 2,8 \cdot I_{3914} \quad (kR)$$

$$S_{erg} = 6,6 \cdot I_{4278} \quad (kR)$$

Measurements in Loparskaya in the period of IGY permitted to estimate in electron flux when there were no aurorae in 1 erg.cm^{-2}sec^{-1} (15). In the minimum of solar activity this value is less, but the intensity of the band λ 4278 Å is never lowered below 50 R, which gives estimate of the corpuscular stream at 0.3 erg.cm^{-2}sec^{-1}.

It is known that the microwave radiation of atomic oxygen is a marked cooling factor of the upper atmosphere. According to estimates of Bates (21) and Nicolet(22) the intensity of radiation of $\lambda = 63\mu$ over 150 km is about 0,1 erg.~~sq.~~cm.$^{-4}$sec.$^{-4}$ and over 100 km about 1 erg.cm^{-2}sec^{-1}. Thus if the corpuscular stream reaches the height of 100 km its intensity is 1 erg.cm^{-2}sec^{-1} which corresponds in our suppositions to thermal efficiency of 0.2 erg.cm^{-2} sec^{-1}. Warming up of the atmosphere over 100 km begins from the intensity of the corpuscular stream 5 erg ($I_{3914} \sim$ 2kR). Let us note the fact that the bright aurorae (IBCIII) can consequently provide though short but intense heating of the atmosphere. Direct measurements of the intensity of electron fluxes gives values of the order of 10^3 erg.cm^{-2}, which corresponds to the thermal energy of 200 erg.cm^{-2}sec^{-1}, released up to the height of 100 km (2.10^{-5} electron volts/particle sec).

Consequently, noticeable heating of the atmosphere by the corpuscular stream can be provided during an order of an hour.

N o t e

In 1961 and 1962 the authors evaluated temperature from twilight flash of helium λ10830 Å. A Fabry-Perot étalon with an image converter was used. One of the photographs is shown in Fig.5. The width of the helium line component is no larger than 0.15 Angström (23,24). This method was used in spring 1962 to study the H_α line in the nightglow. The width of the geocorona H_α line proved to be less than 0.3 Å. Observations carried out for antisolar point enabled to detect some decrease of intensity of the H_α line in this point which dropped off about to halve (taking into account tropospheric scattering).

Legenda

Fig.1. Interferometric photograph of the line λ 5577 in aurora (h ~ 200 mm).

Fig.2. Photograph of the line λ 6300 Å in an A type aurora of moderate intensity.

Fig.3. Photograph of the line λ 6300 Å in a bright A type aurora

Fig.4. Photograph of the laboratory source (yellow line of krypton).

Fig.5. Interferogram of the line He λ 10830 Å in twilight.

References

1. D.H.McPherson, A.Vallance Jones. J.Atm.Terr.Phys., 17, 302 (1960)
2. N.N.Shefov, V.I.Yarin. Coll. "Spectral, Electrophotometrical and Radar Researches of Aurorae and Airglow" No.5, 25 (1961), Results of IGY, Published by the USSR Academy of Sciences.
3. D.O.Wark. Astrophys.J., 131, 491 (1960)
4. T.M.Mulyarchik. Izv.Akad.Nauk SSSR, Ser.Geofiz., No.3, 449 (1960)
5. D.M.Hunten. Ann.Géophys., 17. 249 (1961)
6. CIRA 1961. Report of the preparatory group for an International Reference Atmosphere, accepted at the Cospar Meeting in Florence, April, 1961.
7. A.E.Johanson, A.Vallance Jones. Can.J. phys., 40, 24 (1962)
8. A.Vallance Jones, D.M.Hunten.Can.J.Phys., 38, 458 (1960)
9. P.K.Shuiskaya. Coll. "Spectral, Electrophotometrical and Radar Researches of Aurorae and Airglow" No.5 49 (1961), Results of IGY, Published by the USSR Academy of Sciences.
10. V.I.Yarin. Coll. "Spectral, Electrophotometrical and Radar Researches of Aurorae and Airglow", No.5, 53 (1961), Results of IGY, Published by the USSR Academy of Sciences.

11. A.Dessler. J.Geophys.Res., 64, 397 (1959)
12. A.I.Ershkovich. Isv.Akad.Nauk SSSR, Ser. geofiz., No.2, 254 (1962)
13. M.Sugiura. J.Geophys.Res., 66, 15, (1961)
14. G.S.Golitsin. Isv.Akad.Nauk SSSR, Ser.geofiz., No.7, 734,1961)
15. Iu.I.Galperin. Isv.Akad.Nauk SSSR, Ser.geofiz., No.2, 252 (1962)
16. J.W.Chamberlain. Mém.Soc.Roy.Sci.,Liège, t.IV, 606 (1961)
17. C.E.McIlwain. J.Geophys.Res., 65, 2727 (1960)
18. J.M.Valentine, S.C.Curran.Rep.Progr.Phys., 21, 1 (1958)
19. D.T.Stewart.Proc.Phys.Soc. (London), A68, 404 (1955)
20. D.T.Stewart."The Airglow and the Aurorae". Ed. E.B. Armstrong a. A.Dalgarno. Pergamon Press,London, p.283 (1955)
21. D.R.Bates. Proc.Phys.Soc., B, 64, 805 (1951)
22. M.Nicolet. Planet.Space Sci., 5, 1 (1961)
23. P.V.Shcheglov. Astron.Zhurn., USSR, 39, 158 (1962)
24. P.V.Shcheglov. Coll. "Aurorae and Airglow",No 9, 59 (1962),Results of IGY,Published by the USSR Academy of Sciences.